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9 February 1970

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QUARTERLY PROGRESS REPORT NO. 3
UNDER CONTRACTS N00024-68-C-1149 AND N00024-69-C-1129 (U)

1 July - 30 September 1969

NAVAL SHIP SYSTEMS COMMAND

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UNDER CONTRACTS N00024-68-C-1149 AND N00024-69-C-1129,
1 July - 30 September 1969.

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Proj. Ser. No. SF 11121100
Tasks 8103, 8212, 8515

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I. Project Serial No. SF 11121100, Task 8103

A. AN/SQS-23 SME-PME Playback Program
(L. A. Jeffress)

(U-FOUO) Experimental research associated with this problem is complete, and a final report is being prepared. An outline of the results obtained in this problem was given in the preceding quarterly progress report.

Monaural and Binaural Electrical Models of Auditory Detection
(P. I. Williams and L. A. Jeffress)

(U-FOUO) This study will be used as the basis for a doctoral dissertation. The dissertation is being prepared for clearance and publication.

Computer Simulation of Auditory Detection
(A. D. Gaston and L. A. Jeffress)

(U-FOUO) This study has been completed, and was used as the basis for a doctoral dissertation; it has been published as an ARL technical memorandum (ARL-TM-69-28). An abstract of the report follows.

ABSTRACT

A model of auditory signal detection, based on a previously investigated electrical model devised by Jeffress, was simulated digitally. The model consisted of a bandpass filter followed by a demodulator comprising a half-wave rectifier and a post-detection integrator. The detection performance of the model for gated

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(U-FOUO) sinusoids masked by noise was studied as a function of both the duration of the signal and the time-constant of the post-detection integrator. The performance of the model agreed well with that of the electrical model for comparable conditions.

(U-FOUO) The model was used to investigate the proposition that human subjects in auditory masking experiments might make their judgments about the presence or absence of a signal on the basis of a stimulus event occurring during the observation interval. Specifically, the detection performance of the model was studied under two output sampling schemes, one consisting of samples taken at the termination of the signal, and the other of samples of the maximum of the output waveform. For durations less than about 4 time constants, the two sampling schemes yielded comparable results, but for longer durations the peak sampling scheme led to decidedly superior performance.

Contributions of Psychophysics to Sonar
(L. A. Jeffress)

(U-FOUO) This study has been completed and has been published as an ARL technical memorandum (ARL-TM-69-23). An abstract follows.

ABSTRACT

The major contributions of research in psychophysics to the solution of sonar problems are of two kinds, factual and methodological. In the course of research in hearing, a great many facts have been established that can be called upon to answer questions regarding what a sonarman is capable of so far as his sensory capacities are concerned. The other class of contribution, that of methodology, stems largely from relatively recent developments in what has come to be known as the theory of signal detectability.

B. <u>Naval Ship Systems Command Display Advisory Panel (C. L. Wood)</u>

(U-FOUO) The Display Advisory Panel was inactive during this reporting period.

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II. Project Serial No. SF 11121100, Task 8212

A. Echo Recognition
(K. J. Diercks)

(C) A space frequency crosscorrelation track plot for data recorded from the SKIPJACK model was presented in Quarterly Progress Report No. 2 under Contract N00024-69-C-1129 (U) (1 April through 30 June 1969). For reference, it is repeated as Fig. 1 of this report. These data were processed using the matched filter complex spectrum crosscorrelation technique described in QPR No. 3 under Contract N00024-68-C-1117 (U) (1 July through 30 September 1968). This display (track plot) is visibly "noisy", and although the primary crosscorrelation track is reasonably well defined, numerous secondary tracks, generated by the minor lobes of the correlation functions, are apparent. These same data were reprocessed using the revised computational program described in QPR No. 2. The new output display is shown in Fig. 2. It is noticeably less "noisy" than Fig. 1. The primary correlation track is well defined in both "halves" of the display. This is because there is no longer any lobe splitting in the correlation functions, so that there is less apparent noisiness. The plotting threshold for each figure is 50% of peak correlation value (each function), and the plotted functions are normalized. It appears that the widths of the correlation peaks in Fig. 2 are wider than those in Fig. 1. However, this is not so; the "peaks" evident in Fig. 1 are split correlates of those in Fig. 2. If this splitting is disregarded, it is seen that the two displays are comparable with respect to this feature. The splitting evident in Fig. 1 is unexplained.

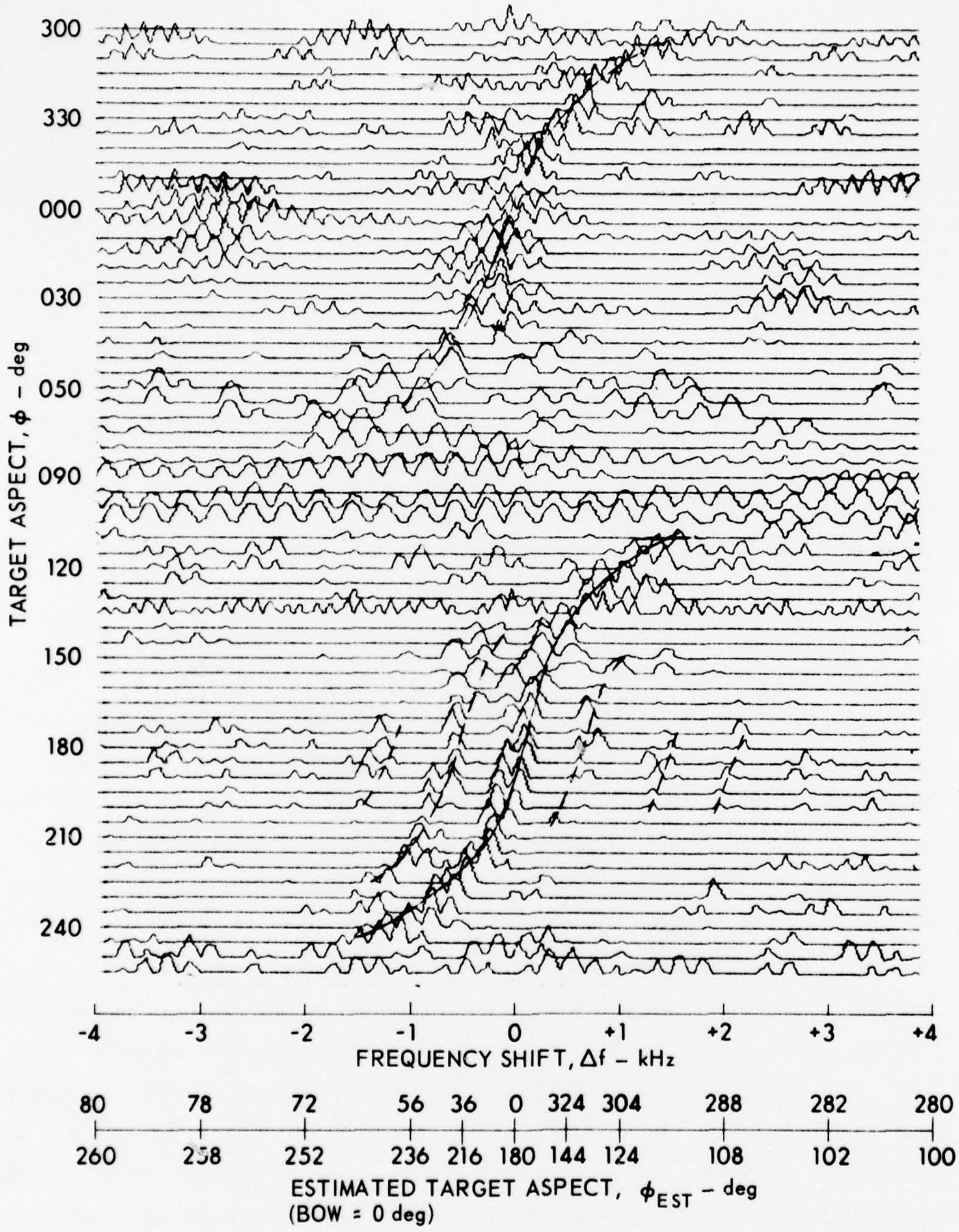

FIGURE 1
SPACE-FREQUENCY CROSSCORRELATION TRACK PLOT (U)
SKIPJACK MODEL f_o = 240 kHz T = 7.3 msec
W = 40 kHz B = 2.3 ft R = 410 ft

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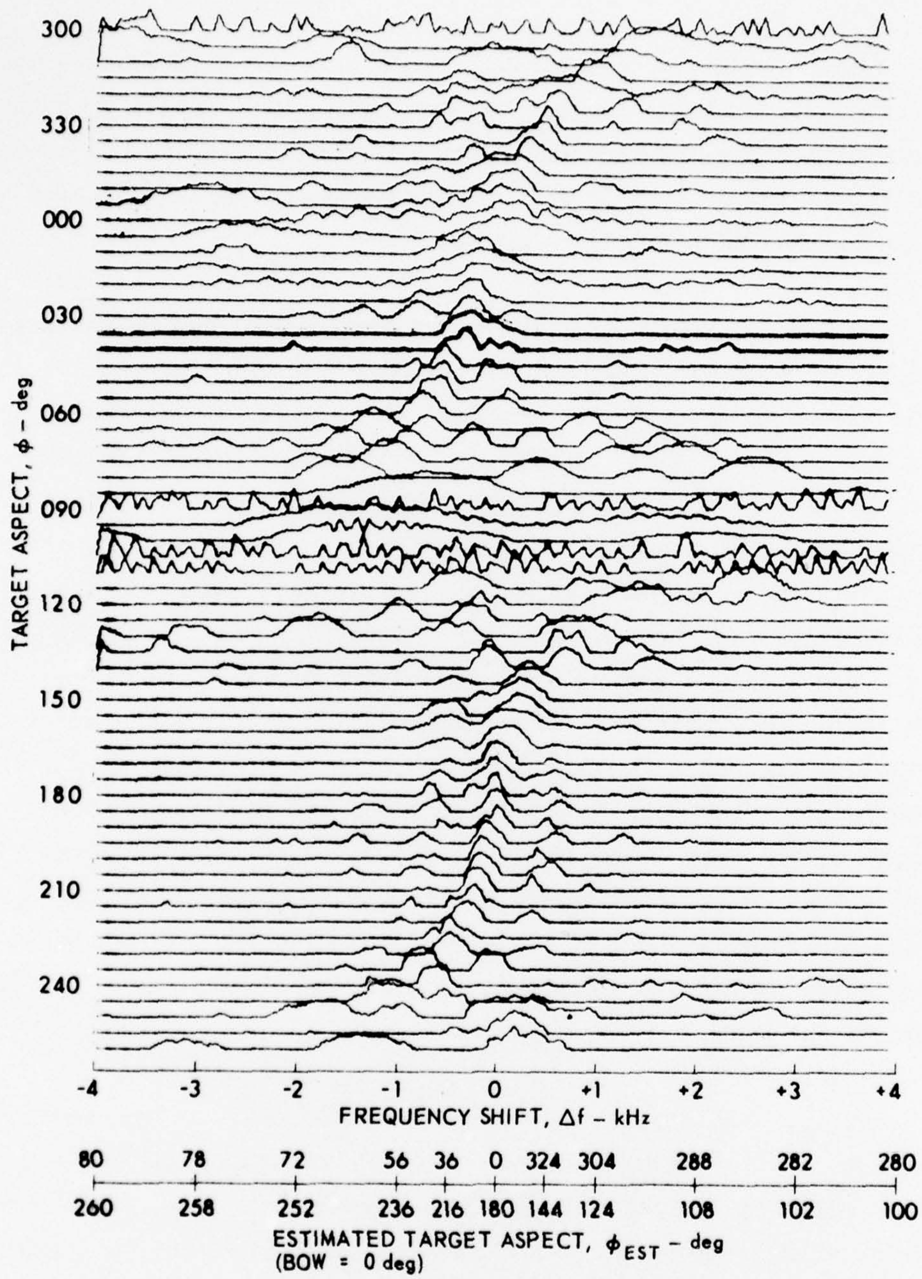

FIGURE 2
SPACE-FREQUENCY CROSSCORRELATION TRACK PLOT (U)
SKIPJACK MODEL FFT PROCESSING
f_o = 240 kHz T = 7.3 msec W = 40 kHz
B = 2.3 ft R = 410 ft

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(C) The reduction in noisiness in Fig. 2 is partly a consequence of improved correlation side lobe suppression. The revised computational program is being examined to ascertain why this occurs, and whether additional improvement in side lobe suppression may be achieved by changing the FFT parameter values.

(C) In QPR No. 2 (1969) it was noted that around bow target aspect the stern reflecting surfaces of the SKIPJACK model are in the shadow zone of the target. It is felt that this effect is manifested in the degradation (spreading) of the correlation functions of Fig. 2 near bow aspect (000 ± 20 deg). Correlation value decreases from 0.65 to 0.35 between 330 deg and 000 deg, respectively, and increases again to 0.6 at 030 deg. Correlation value will be a parameter in a classification algorithm using space-frequency analysis. Accordingly, any degradations caused by targets and not directly related to the space-frequency phenomenon may yield a false dismissal. Additional data from the SKIPJACK model are available to further evaluate this observation. However, to establish baseline performance, a new target of the same genre as the ARL 7-ball line target will be fabricated. A crude attempt will be made to model the SKIPJACK model using discrete scatterers. Data will be collected and processed during the next quarter and described in the status report for that period.

(U-FOUO) During this reporting period a computational program to simulate scattering by a linear array of reflectors was written. The ARL 7-ball line target was modeled. Signal parameter values used in the STARLITE measurement program with that target were used in the simulation. Thus, the analytical model provides a reference for evaluating the experimental results, especially those anomalies which were attributed to target effects--reradiation by the reflector supporting rod--or to low signal-to-noise. S/N value of the simulated

(U-FOUO) data is not infinite due to sampling "noise", but it is at least very large. Data were processed using the NOVELCOR algorithm (DRL-TM-68-25). Both STARLITE and SLOSTARSIM (target rotating in the field of a single transducer) were examined.

(C) Figure 3 is the output display of a STARLITE simulation. The parameter values are: T = 10 msec, W = 10 kHz, f_o = 110 kHz, B = 0.35 m, R = 22 m, L = 2 m. (Experimental data were recorded at f_o = 220 kHz, T = 5 msec, and W = 20 kHz. Therefore, the two sets of results are not directly comparable.) Simulations were performed at 5 deg aspect increments from bow to beam. The STARLITE phenomenon is evidenced by the track in the display. This track is lost at φ = 15 deg; peak correlation occurs at a time shift of approximately 0.2 msec (which yields an estimated aspect of 77 deg). The correct shift value, 3.3 msec, is still within the time window, which implies that loss of track occurred because of a loss in correlation. Why this occurs is not fully understood. Comparable experimental data showed a loss of track at $\varphi \approx 25$ deg, again because of loss of correlation. However, recall that valid correlations between measured spectra of the 7-ball line were achieved through φ = 10 deg (QPR No. 3 under Contract N00024-68-C-1117 (U)). The phenomenon will be examined experimentally and described in later status or technical reports.

(C) Note, also, in Fig. 3 that peak correlation at φ = 60 deg occurs at a negative time shift, which yields an estimated aspect of -68 deg. This occurs in the middle of what may be called the "reliable aspect range". This observation was examined by simulating and crosscorrelating the echo signals between 55 deg and 65 deg in 1 deg increments. The output display is shown in Fig. 4. Included below the plot is a tabulation of the measurement parameter values. Correlation breakdown occurs at φ = 60 deg and 61 deg and at φ = 56 deg. The correlation

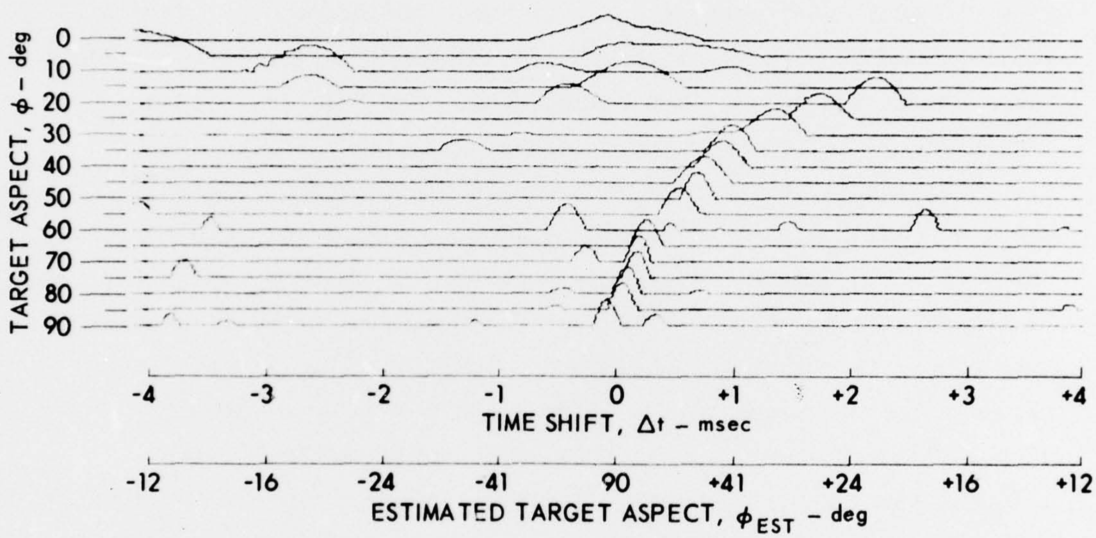

FIGURE 3
SPACE-TIME CROSSCORRELATION TRACK PLOT (U)
STARLITE SIMULATION
f_o = 110 kHz T = 10 msec W = 10 kHz
B = 1.15 ft R = 72 ft

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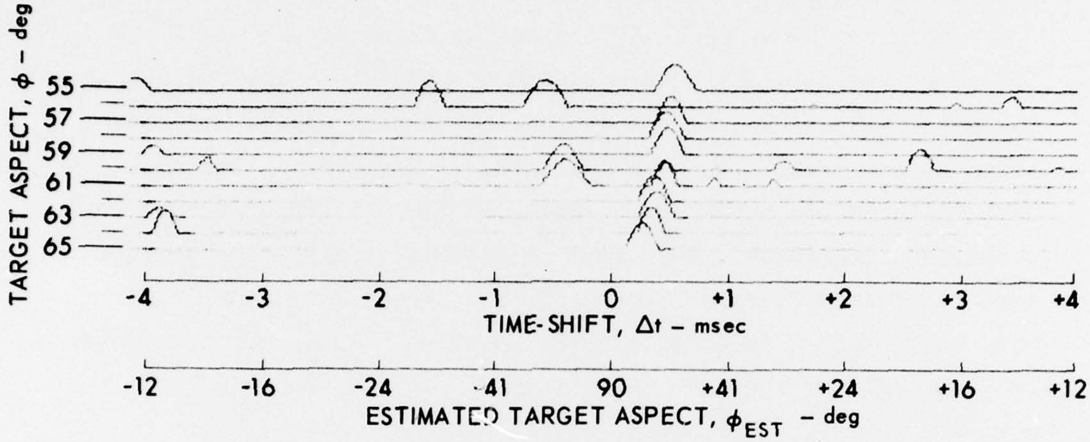

ϕ – deg	Δt – msec	ϕ_{EST} – deg	CORRELATION
55	0.62	54.7	0.71
56	-1.49	-30.4	0.46
57	0.59	56.0	0.67
58	0.55	58.1	0.81
59	0.56	57.6	0.78
60	-0.36	-67.9	0.46
61	-0.34	-68.9	0.44
62	0.44	63.5	0.73
63	0.46	62.1	0.73
64	0.42	64.5	0.74
65	0.34	69.0	0.62

FIGURE 4
SPACE-TIME CROSSCORRELATION TRACK PLOT (U)
STARLITE SIMULATION
f_o = 110 kHz T = 10 msec W = 10 kHz
B = 1.15 ft R = 72 ft

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(C) values at the correctly located peaks are uniformly large ($\geqq 0.62$), whereas they are small at the incorrectly located peaks ($\leqq 0.46$), indicating a general loss of correlation at each of the latter aspects. Presumably the specific aspect values at which breakdown occurs are unique to the specific configuration of reflectors and the signal parameter values, and on the average, over many echoes and many targets, the effect would be negligible. However, understanding of its "failures" is necessary to evaluate the utility of STARLITE as a classification input. Therefore, additional analyses of these data (and other data from both the experimental and analytical records) will be performed to ascertain the specific features of the scattering geometry and for the echo signals which cause or contribute to the observed correlation losses.

(C) Figure 5 is the output display for the SLOSTARSIM simulation. The pulse length value for these results is T = 5 msec. The data were generated by "transmitting" signal 1 and "receiving" echo 1 along an axis making an angle φ with the target axis, and by transmitting and receiving a second set of signals along an axis which makes an angle $(\varphi - \psi)$ with the target axis. ψ is the receiver parallax angle. Note that the correlation track is "continuous" through $\varphi = 15$ deg. (Although the correlation peak along the $\varphi = 20$ deg trace yields an incorrect estimate of aspect angle, $\varphi_{EST} = 76$ deg, there is a local peak at the correct time shift value which renders the track continuous in this region; similarly for $\varphi = 30$ deg). Also, in this display there is no evidence of correlation at the correct time shift value along the $\varphi = 60$ deg trace, not even the small peak seen along this trace in Figs. 3 and 4, illustrating once again the interaction of signal and target to yield loss of or degradation in correlation (independent of other STARLITE limitations).

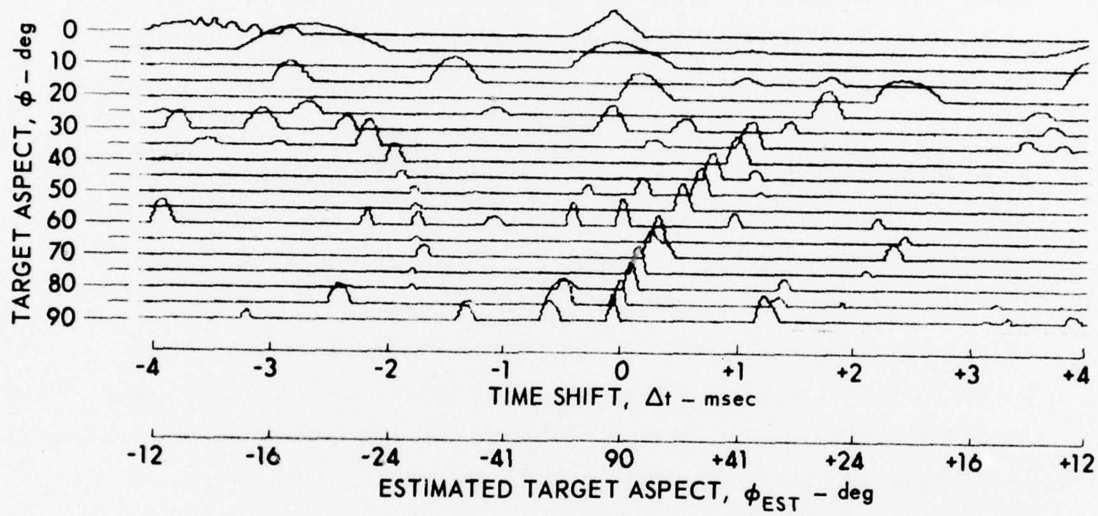

FIGURE 5
SPACE-TIME CROSSCORRELATION TRACK PLOT (U)
SLOSTARSIM SIMULATION
f_o = 110 kHz T = 5 msec W = 10 kHz
"B"= 1.15 ft R = 72 ft

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(U-FOUO) Additional multisensor measurements of scattering by simple line and nonline targets were recorded during this quarter. The nonline target forms were emphasized; that is, three length-to-thickness ratios were used, plus a random configuration, plus a 7-reflector line array for reference. The targets were formed without the use of metallic supporting rods to avoid the anomalies caused by such rods in earlier targets (see QPR No. 3 under Contract N00024-68-C-1117 (U)). Both LFM and equivalent bandwidth signals were recorded using a sequenced transmission format. Three FM pulse lengths paired with two FM bandwidths were alternated with equivalent bandwidth short pulse transmissions. Three receiving hydrophones were used.

(U-FOUO) These data were recorded so that questions or limitations left unanswered or undefined by the earlier ARL STARLITE work with simple geometric targets could be resolved, that is, effective perturbations from linear geometry caused by reradiation by the reflectors' supporting framework, ambiguities resulting from target thickness, and better definition of the constant of proportionality in the ARL derived empirical relation describing STARLITE utility (Eq. (5), DRL-TM-68-10). These data are being processed, and the results will be presented in the status report for the next quarter. These results will be combined with earlier reported results (concerned with different processing methods, S/N value, etc.) and will be issued as ARL Technical Report No. 69-37, "Space-Frequency Analysis of Acoustic Scattering by Line and Nonline Targets". This report will formally summarize (and essentially conclude) ARL's work with simple line and nonline target forms.

(U-FOUO) An attempt was made to simulate (scale) a school of fish by enclosing minnows inside a large flooded weather balloon. Measurements showed that the balloon was acoustically transparent and would not contaminate the measurements. However, a single balloon could not be

(U-FOUO) kept intact for more than a few hours. Therefore, no measurements have yet been made. A second attempt will be made during the next quarter; a two-skinned balloon enclosure will be tried. The target will be positioned such that echoes from both the submarine (SKIPJACK model) and the nonsubmarine may be simultaneously recorded on the same magnetic tape permitting direct comparison of results.

(U-FOUO) The high speed mechanical scanner for simulating RDT is completed. Alternating RDT/SDT data from the submarine and the nonsubmarine (school of fish) will be collected and a side-by-side analysis of echo highlight structure obtained with the two transmission forms will be made. Results will be described in the status report for the next quarter. A technical memorandum describing the simulator and its performance will be issued during the next quarter, entitled "Mechanically Simulated RDT of the AN/SQS-23", ARL-TR-69-18, by W. W. Ryan.

B. Operations Analysis
(R. K. Goodnow)

1. Dubbing of the Sonar/ASPECT Classification Test (S/ACT)

(U-FOUO) During the months of July and August the Sonar/ASPECT Classification Test (S/ACT) was dubbed from the USS ROGERS (DD 876) data tapes, according to the selection of data made earlier and reported in the last quarterly progress report. The dubbing was carried out in two steps, because tapes made on our original PME cannot be played back on the second PME which was obtained for dubbing tests.

(U-FOUO) The head gap scatter of the No. 2 PME was found to be nonrandom, indicating a curvature of the head gap mean line. This was found by making phase measurements across the head, during which phase disparities were found to be as great as 60 deg between center and edge tracks. The edge tracks of the No. 2 PME lag the center tracks by about 40 deg on the outboard edge and about 60 deg on the

(U-FOUO) inboard edge. Any tape recorded on this machine can be played back on it with the perfect phase reproduction, but tapes made on it cannot be played on other machines, and tapes made on other machines cannot be played on it without some loss of phase integrity of the signals. Measurements of the degradation of beamforming by the AN/SQS-23 caused by this curvature have not yet been made. A method of making these measurements has recently been devised, and will be tried as soon as possible. It is thought that beamforming will suffer significantly only about the beam (090 or 270 deg relative), since the edge tracks are recorded from the transducer staves nearest the stern of the ship.

(U-FOUO) Because of this anomaly in the No. 2 PME, tapes were copied in two steps. The original tapes were played on the No. 1 PME and copies of the selected events were dubbed on the No. 2 PME (No. 2 master tapes). These second generation tapes were then played back on the No. 2 PME and redubbed on the No. 1 PME. As a result, the tapes to be used as actual testing tapes are third generation tapes. This should make no practical difference, since the Fleet ASW School NASTAD has gone as far as eighth generation without noticeable degradation of the signals. The worst effect is the doubling of time used for making copies of the USS ROGERS tapes. In effect, we now have a complete set of master tapes for the preliminary selection of events of the S/ACT, and when the final selection of events for this test is completed, the No. 2 masters can be used to generate final copies of the S/ACT for use in testing.

(U-FOUO) The S/ACT will be validated by the comparison of test scores with the scores achieved on the OCPT by the same individuals. Test results will be subjected to an item analysis (for each event) to match final version test scores with those for the OCPT. The main consideration is that the S/ACT should match the OCPT; that it

(U-FOUO) be an identical, not an improved, test. The final form of the S/ACT will be tailored by selection of those items that will force the final results into extreme similarity to those results found for the OCPT. Continuity must be maintained between tests so that we can continue to use our only valid means of comparison of results: that the testing was done with the same or extremely similar material.

2. Navy Reserve Sonarmen Testing Program

(U-FOUO) Because of the increased workload on the Playback Facility it has been determined that evening work was desirable for best use of the facility and for timely results. Concurrently the local Naval Reserve Unit expressed interest in having their sonar technicians get practice on sonar equipment for their training sessions.

Messrs. R. K. Goodnow and A. D. Gaston of ARL visited the Reserve Center in August and explained the ARL classification testing program to the officer cadre of the center. Arrangements were made for the sonarmen to fulfill their reserve obligation by meeting at the Reserve Center the first Monday of every month, and then spending the remainder of the month (three or four weeks) acting as test subjects at ARL. Eight sonarmen were available to start the program in September, and two or three more will perhaps be available to enter the program at a later date. A tentative working schedule was arranged on a second visit to the Reserve Center. This schedule involved evening work, both to accommodate the working and school hours of the Reserve sonarmen and to avoid interference with the heavy work load of the Playback Facility.

(U-FOUO) The training plan for the first part of the testing program can be summarized in five steps.

(U-FOUO) Step 1. Train all subjects (operators) in use and interpretation of AN/SQS-23 controls and displays.

Step 2. Train all operators in classification using the Navy classification textbook (NAVPERS 92728, "Target Classification Using Active Scanning Sonars", BuNavPers, April 1960. (CONFIDENTIAL)

Step 3. Instruct all operators in using the (above) acquired knowledge by playing practice tapes, by having them use the sonar, and by pointing out to them the signal parameters taught in (2).

Step 4. Teach all operators the use of the 10-point, forced choice rating scale for indication of classification decisions.

Step 5. Start the testing program by testing all operators with Operator Classification Performance Test (OCPT) to establish their "baseline" performance curve.

(U-FOUO) This training program must be flexible, so that a judgment can be made on the success of each step as it is completed. It is immediately apparent that the time necessary for Step 1 will be altered, because of the background experience of the eight subjects. One was an AN/SQS-23 operator, one an AN/SQS-26, one an AN/SQS-29, one an AN/SQS-30, three AN/SQS-31, and one an "oceanographer".

(U-FOUO) The testing schedule started on 1 September 1969, and the month of September was used almost entirely for training the subjects. One subject (the AN/SQS-23 operator) started taking the Operator Classification Performance Test (OCPT) during the week of 22 September, and five more subjects started during the week of 29 September through 5 October. Another subject (AN/SQS-26 operator) is expected to start the OCPT during the week of 13 October. The eighth subject, the "oceanographer", will require training as an active sonar operator, and may not start the OCPT until November. It is presently expected

(U-FOUO) that most of the subjects will complete the OCPT during October or early November, and then will start on the S/ACT. It appears that two more subjects will join the program during October.

(U-FOUO) It is necessary to give both tests, OCPT and S/ACT, to all subjects for two reasons: first, to maintain the continuity of testing on the baseline test, the OCPT; and second, to validate the S/ACT as a comparable test. Further, the continuity of test material can be established only by carrying out this validation procedure. It can be stated with a high degree of assurance that future testing will use test material identical, or at the least extremely similar, to those that have been used for the testing program thus far. The validation will prove a commonality of data so that direct comparison of test results can be made for all classification devices, aids, and schemes either tested or to be tested with operators.

(C) Upon completion of the testing on S/ACT, these subjects will be trained and then tested on: the TRR (Tactical Range Recorder), ASPECT, HHIP, MITEC, and Monoppler/FACT. This program will extend through at least September of 1970. Each testing period is planned to take about one month, with the training periods flexible to ensure that each subject is trained to at least a moderate level of proficiency in the use and interpretation of each device.

(U-FOUO) It is presently planned to issue one final report on this testing program late in 1970.

3. Continuing Work

(U-FOUO) The analysis of the dubbing quality verification photographs is being carried out by a part-time student worker on a low priority basis. It is expected that this will be completed during the fourth

(U-FOUO) quarter of 1969. Preliminary results indicate that the dubbing program for transferring the ARL data base from SME to PME format was a qualified success. A significant number of photographs have been found that indicate a less than perfect transferral of data from the SME to the PME; some 5 to 10% of the PME tapes appear to be faulty copies. The reasons for faulty dubbing will be ascertained, and the faulty copies will be redubbed on an "as available" basis.

(U-FOUO) The analysis of test results is also being continued by a part-time student worker on a low priority basis. It is thought this work will give, as completely as possible, a knowledge of the tests and their results. One example of the type of analysis being carried out is the compilation of subjects' comments about each event of the OCPT; by these we can ascertain what the better, and poorer, classifiers saw in each event that helped them to reach their classification decisions, right or wrong.

C. Naval Ship Systems Command Active Sonar Classification Advisory Panel
(S. P. Pitt)

(U-FOUO) In accordance with the review functions of the Classification Panel, two separate research efforts sponsored by NAVSHIPS, Code OOV1C, were examined during this quarter. A rough draft of the final report from Raytheon, "Optimum Processing Techniques", was reviewed, and comments were verbally conveyed to NAVSHIPS. These comments led to direct communication with Raytheon, which further led to a conference in Washington, D. C., between representatives from Raytheon (Drs. R. Pascha and L. Leblanc), NAVSHIPS (CDR H. Cox, Messrs. D. Strickler, and K. Buske), NSRDC (Mr. T. Kooij), and ARL (Mr. P. Pitt). The report was considered generally unsatisfactory, as many specific shortcomings were pointed out, and Raytheon subsequently agreed to provide a revised version.

(U-FOUO) Mr. Pitt also traveled to Purdue University to attend a meeting with Dr. E. Patrick and Mr. K. Buske. Purdue's work and their capabilities were discussed relative to the overall capabilities of contractors currently working under Code OOV1C. Specifically, Purdue's ability to handle AN/SQS-23 stave data in a manner such as described in previous progress reports was discussed, and it was found that until Purdue obtained either increased digital magnetic disk or magnetic tape capabilities, their facility would not allow for efficient processing of these data. They expected to obtain such capabilities shortly, and analog tape with this type of data was left with them for future processing.

III. Project Serial No. SF 11121100, Task 8515

A. Systems Analysis
(S. P. Pitt)

(C) During the third quarter, two problems being worked on in Systems Analysis were examined as to the likelihood of "payoff" (production of positively useful results) relative to other studies; especially in light of the limited technical manpower, these two problems were found not to warrant significant further effort at ARL at this time. These problems were the study of the applicability of likelihood ratio processing of echoes for classification and the AN/SQS-23 stave data analysis. In addition, the echo structure variation study was considered to be essentially complete, and it is anticipated that a technical report will be issued by the end of the contract year. Each of these studies is discussed further in the following paragraphs.

(C) Although the model studies phase of the likelihood ratio work has not progressed satisfactorily because of problems with experimental conditions, the results with submarine data from both the model study and the echo-to-echo correlation study indicated the extreme sensitivity of the process to target and medium parameters when both amplitude and phase information are used. In comparison to the statistical analyses of reverberation and other nonsubmarine phenomena, the study was considered to be secondary in importance. Therefore, the results of the likelihood ratio study to date will be summarized in the progress report for the fourth quarter.

(C) On the other hand, whereas the stave data analysis were considered to be of great importance, the manpower and hardware necessary for working with the problem at ARL is such that the effort in areas with greater immediate potential would be diminished. Therefore, stave data analysis will be carried on at a low level as time and equipment allows, with reporting primarily in the progress reports. The installation of a communication link between the DDP-516 and the CDC 3200 computers would allow for much more efficient handling of this type of data, and the program will be reviewed with this in mind when such a link is established.

(U-FOUO) The echo covariance study is being terminated for essentially the same reason as the stave data study: continued advancement would require data not presently in hand, and collection of such data would require more manpower and hardware than can be justified. In this case, however, enough data have been processed to produce a technical report, which we hope to complete during the next quarter.

(C) The results from the echo length study, on the other hand, will be applied in a two-dimensioned process. Current plans are to develop a threshold algorithm to provide "dimension" estimates in two dimensions (range and bearing) for application to submarine and nonsubmarine data from the AN/SQS-23 video scanner. The development of such an algorithm will require knowledge of reverberation statistics in both space and time, and the relationship of the "best" threshold to those statistics. Results of both the single beam reverberation statistics study and the echo length study will be highly useful here. In addition, the hardware facility and A/D capabilities described in the preceding progress report (ATOD23) will be required to obtain digital data. These data have a coincidental utility to the AN/SQS-23 Modest Improvement Program, and partly because of the deadline

(C) associated with that program, the hardware hookup between the PME//AN/SQS-23 Playback Facility (video scanner) and the A/D facility has been completed.

(U-FOUO) The work on reverberation from a single beam continued with the development of software for performing statistical tests, mostly those suggested by Dr. David Middleton. Tests for homogeneity, independence, and normality (Shapiro-Wilk) have been implemented and checked out. These programs will be applied to sequences of returns from a particular type of transmission to test for existence of an ensemble and to determine statistics of the sequence if it qualifies as an ensemble. These tests will provide confidence in any data being analyzed for statistical parameters over many pings. The tests have been applied to one particular sequence of reverberation returns digitized for MIP, but results are as yet only preliminary. It is expected that the tests will be applied to a large body of CW and FM reverberation data during the next quarter.

(U-FOUO) The reverberation data digitized for MIP were displayed through the D/A on a Sanborn 6-channel strip chart recorder, which takes the logarithm (to any desired base) of the envelope and then D/A converts simultaneously on 4 channels. With this new capability, about 280 returns were plotted in slightly more than 1 hour.

(C) This new capability was used in displaying correlation functions in the study of the relationship of quantization for replica correlation and signal-to-noise ratio. These data were produced to complete the data base for the joint report with Naval Undersea Research and Development Center (NUC), and a revised rough draft is being compiled. Figures and a description of the results of this study will be included in the next progress report.

(U-FOUO) Mr. Bryson Pennoyer visited ARL on 4 and 5 September 1969 to help with the data processing and rewriting, and to discuss the final rough draft. Because he is temporarily leaving NUC for graduate studies, the final version will have to be worked out by collaboration between ARL and the remaining personnel at NUC who were most closely involved. It is hoped that a final rough draft with all figures can be compiled at NUC by the end of the year, although the priority for this report is relatively low.

(U-FOUO) A final version of the study on the use of digital quadrature methods on general bandlimited waveforms was completed and submitted for publication to the Journal of the Acoustical Society of America during this quarter. The paper shows that quadrature methods can be used on low pass waveforms, bandpass waveforms, or any combination thereof, as long as an upper bound on frequency components exists. It is felt that this study virtually completes the theory on quadrature sampling techniques.

(U-FOUO) A technical report (ARL-TR-69-27, August 1969) describing the application of the FFT to a periodic waveform was published during this quarter. The report deals with both first-order sampling techniques and quadrature sampling techniques, and provides both an analytic rationale for some of the parameters associated with the FFT and operational considerations when using the software, with examples given for the different types of sampling methods.

(U-FOUO) The analog interfaces associated with the A/D system were completed, installed, and heavily used during this quarter. These interfaces provide for a much more efficient A/D-D/A operation than the previous setup.

(U-FOUO) Formal preparation of the catalog of digital data mentioned in the preceding progress report was begun, with initial emphasis on data from ASPECT-type transmissions. A large amount of this type of data was produced for the echo covariance study, and this type of data represents a large portion of our total digital library. It is expected that the first version of the log will be produced during the next quarter.

B. Computer Applications Section
(J. K. Vaughan)

(U-FOUO) The recent developments can be divided into four categories: 1) new computer programs, 2) addition of subroutines to the computer library, 3) modifications to existing computer programs, and 4) changes to the A/D facility.

1. New Computer Programs

(U-FOUO) a. DTOA - This program was designed as a means of rapidly transferring the data digitized for the Modest Improvement Program from digital tapes to a visual record. Four signals recorded on digital tape are transferred to computer memory. During the transfer process the envelope of the data is computed, averaged over n consecutive samples, and packed into computer memory. The logarithm of the data is then taken and displayed through the D/A interface. The dynamic range of the D/A output is under operator control. The data are then transferred to a strip chart recorder. This technique, as compared to the incremental plotter, allows large volumes of data to be plotted in a reasonable amount of time; that is, four signals are plotted simultaneously in less time than one could be plotted on the incremental plotter.

(U-FOUO) Although this program was generated for a specific project, it will be modified in the future for a more general purpose usage.

(U-FOUO) b. PHASER - This program is designed to compute the instantaneous phase from the quadrature components of a signal. The results are buffered onto a digital tape so that the data may be processed by other programs.

(U-FOUO) c. SHIFTER - Data were digitized in quadrature from twelve stave outputs. These data were to be used to study spatial correlations. However, the samples needed to be sampled simultaneously before correlation could be meaningfully accomplished. Program SHIFTER was designed to shift the samples in time via the Fourier transform, so that the signals are aligned in the time domain.

(U-FOUO) d. FASTPOWR - The Fast Fourier Transform (FFT) is used to compute the power spectra of signals which have been stored on digital tape. The power spectra may be computed using quadrature or uniformly spaced samples of the signals. The results are plotted and stored on digital tape.

2. Computer Library Additions

(U-FOUO) A package of three subroutines designed to input data from digital tape was completed and added to the library. These routines are INPTAPE, FINDSEQ, CHANNEL1, and LIGHTS.

(U-FOUO) a. INPTAPE - This subroutine is a real time buffer of integer data (12 significant bits) from magnetic tape and it will accept any format of the data. A brief description of the various options is listed.

(U-FOUO) (1) The data may be packed (2 samples/word) or unpacked.

(2) Up to 8 channels of multiplexed information may be transferred into separate arrays.

(3) Only every I^{th} sample may be transferred.

(4) Quadrature samples may be selected if desired or if data have been previously quadrature sampled, both the X and Y quadrature records are transferred.

(5) The arithmetic mean of the data is accumulated for each record.

(6) The first and last sample to be transferred may be specified.

(U-FOUO) b. FINDSEQ - The subroutine FINDSEQ is called by INPTAPE. Basically the routine optimally searches a magnetic tape for a specific record. After locating the record, the tape is positioned at the beginning of the data record.

(U-FOUO) c. CHANNEL1 - This subroutine is called by both the subroutines described above and may be described as a general purpose tape status checking routine with tape tables, tape handling routines, and error printing routines.

(U-FOUO) d. LIGHTS - The digital write section of the D/A interface is accessible via this subroutine. All of the A/D and D/A programs use this subroutine to display information to the operator.

3. Program Modifications

(U-FOUO) Several programs have been modified to allow more generalized usage. The most significant modification was to the program MODSUB, which was designed to simulate echoes from point

(U-FOUO) reflectors located along a line. The modifications include the following items:

a. a second line array of point reflectors may be specified,

b. a second receiving hydrophone may be selected,

c. the array(s) may be assigned a velocity and course,

d. the number of pings and the ping rate may be specified with one output record generated per ping.

4. <u>A/D Facilities</u>

(U-FOUO) Preliminary work was started to redesign the patch board which connects various equipments to the A/D interface. Basically the redesign is the reassignment of connections to the patch board and the associated art work on the face of the board.

(U-FOUO) A 6-channel Sanborn strip chart recorder was connected to the A/D-D/A interface. This added facility provides a means of rapidly plotting data, including data stored on digital tapes via the D/A interface.

C. <u>Classification Prediction Model</u>
<u>(J. K. Beard)</u>

(C) Efforts to obtain prediction model results for targets in shadow zones not described by two gradients, such as moderately deep submarines in a sea with a negative surface gradient, cannot be obtained with available propagation loss estimates. Ray theory fails in shadow zones, and both AMOS and the bilinear normal mode model can only predict propagation loss reliably in the two gradients nearest the surface. A curvilinear normal mode technique has been found which will model a general velocity gradient, and sufficient analytical results have been obtained to show that the new model will

(C) be as fast as the bilinear model and thus useful in system parameter optimization. In addition, the new normal mode model is capable of modeling SOFAR channel and bottom bounce propagation, and is promising for application to buried mine classification studies. Problem areas to be resolved are primarily the determination of polynomial fits to certain types of velocity profiles and the theoretical relation between different forms of the solution to the normal mode depth equation. Numerical techniques are available to handle these problems, but analytic solutions to these problems will improve the speed and accuracy of the model in practical application.

D. Cross-Range Resolution Improvement (J. F. Willman)

(U-FOUO) Preliminary measurements were made using the 20-output hydrophone array and the SKIPJACK submarine model at the Lake Travis Test Station (LTTS). The simplified SSI display was used as an indicator of phase coherence of echoes at various signal-to-noise ratios (S/N). By using data acquired on echo level, noise level, target strength, and variations of these quantities, a 20-channel signal preamplifier with gain and phase adjustment has been built and given initial tests. At present, some minor revisions are being made to improve signal isolation between channels. Also, the previously used SSI circuitry is being combined with the gain and phase matrix to provide maximum flexibility and utility in the data acquisition system. Provisions are also being made for the addition of time synchronization signals to each data channel for recording on magnetic tape. The data acquisition system will be completed and put into use during the next quarter.

(U-FOUO) During the preceding quarter, some consideration was given to various methods of synchronizing the experimental data recorded on magnetic tape. Dynamic skew errors in magnetic tape recorders

(U-FOUO) introduce excessive phase shift between tracks unless some means is used to provide adequate synchronization. Accordingly, several synchronization techniques have recently been investigated and compared during this quarter. All techniques investigated are compatible with quadrature-sampling A/D programs available at ARL. The 80 kHz experimental data will be recorded at 60 ips. By using the technique selected, a 160 kHz continuous sine wave signal and a pulsed 240 kHz signal will be added to each signal track to provide time synchronization. The 240 kHz pulse will provide the delayed time reference occurring just before each echo is received from the target; this pulse is used to provide the interrupt signal to the computer to enable the A/D converter during data digitizing. The A/D quadrature samples are taken over the time interval of the echo return at each zero-crossing of the 160 kHz reference. A phase locked oscillator is used to reduce tape dropout problems for A/D conversion. For various test signals, the standard deviation computed between any two tracks for the signal digitized from the 1/2 in. recording amounted to approximately 1.5 deg of phase shift at 80 kHz. At a recording speed of 60 ips, the corresponding time difference on the tape is approximately 0.05 μsec. Based upon published instrumentation tape recorder specifications for dynamic skew error across a single head stack, the maximum error for a record and reproduce operation is approximately 40 times as great without synchronization of each track.

E. Digital Beamformer
(W. T. Adams)

(C) The basic design of the digital beamformer that began in the second quarter was completed in this quarter. Parts were ordered for construction of the beamformer and most of the printed circuit cards were designed. The geometric analog-to-digital converter was redesigned to give a 72 dB dynamic range. Preliminary design of the

(C) detector-averager was completed during this quarter. Testing of individual printed circuit cards and the construction of the detector-averager will take place in the fourth quarter.

F. Sonar Detection System
(S. P. Hufnagel)

(U-FOUO) Final authorization for the procurement of the Honeywell DDP-516 computer and necessary peripheral equipment was obtained. An evaluation of the system requirements had been performed during the second quarter and a detailed breakdown of the computer system specifications was presented in Quarterly Progress Report No. 2. The only modification to the system, as presented in QPR No. 2, is that in the analog-to-digital converter totally compatible Analogic hardware modules were approved, thereby reducing engineering difficulty. This change caused no alteration in the frequency capability of the system.

(U-FOUO) An interface evaluation of the system requirements was performed to determine an efficient and compact implementation of the necessary digital functions. These logic functions must be generated to allow transfer of information between the computer and any subsidiary device, that is, the beamformer. The interface that was accepted is device modular and is an entire system interface block unit, which will be efficient and compact but discourage subsystem usage independent of the central processor.

(U-FOUO) Delivery of all system peripheral components, except the IBM Selectric Typewriter, occurred during the third quarter. Detailed design, layout, and construction of the printed circuit interface cards is expected to be done during the fourth quarter of CY 69. Final completion of construction and full computer system operation should be completed during the first quarter of CY 70.

(U-FOUO) No further tests or changes in the computer software to perform the detection algorithm were performed during the third quarter because of the emphasis on hardware system analysis and design.

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